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**Fukuda**

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(54) **METHOD OF MANUFACTURING A CIRCUIT SUBSTRATE**

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**H05K 1/18** (2006.01)

(Continued)

(52) **U.S. Cl.**

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(58) **Field of Classification Search**

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2224/81193; H05K 2924/15151; H01K 1/183; H01L 21/481; H01L 21/4863; H01L 23/13; H01L 23/16; H01L 23/49816; H01L 23/49827; H01L 24/81; H01L 2224/16226; H01L 2224/81136; H01L 2224/81801; H01L 2924/01004; H01L 2924/01029; H01L 2924/01033; H01L 2924/01056; H01L 2924/14; H01L 2924/15153; H01L 2924/1517; Y10T 29/4913; Y10T 29/49139; Y10T 29/49165; Y10T 156/1052; Y10T 156/10 See application file for complete search history.

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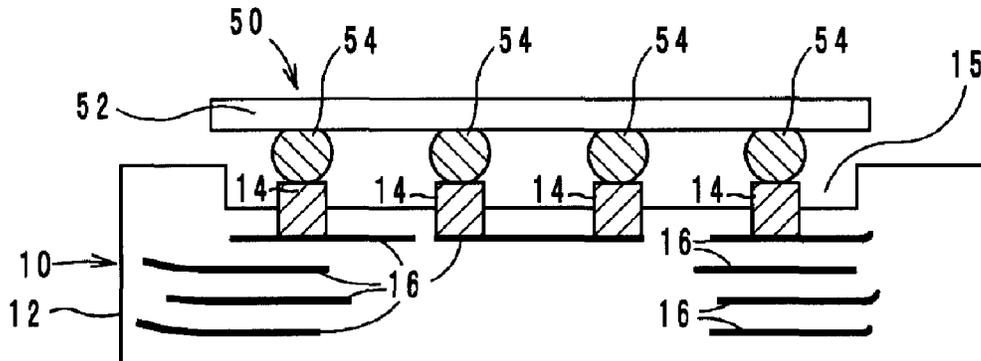
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(74) *Attorney, Agent, or Firm* — Keating & Bennett, LLP

(57) **ABSTRACT**

A thin circuit substrate and a circuit module are arranged such that the circuit module includes an IC mounted on a circuit substrate, the IC includes an IC body and a solder bump located on a mounting surface of the IC body, and the circuit substrate includes a substrate including a recess formed by recessing a portion of a mounting surface of the substrate on which the IC is to be mounted, and a terminal protruding from the mounting surface of the substrate. The terminal is to be electrically connected to the solder bump.

**6 Claims, 11 Drawing Sheets**



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- (51) **Int. Cl.**  
*H01L 21/48* (2006.01)  
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*H01L 23/498* (2006.01)  
*H01L 23/00* (2006.01)  
*H05K 1/11* (2006.01)  
*H05K 3/00* (2006.01)  
*H05K 3/40* (2006.01)  
*H05K 1/03* (2006.01)  
*H05K 3/24* (2006.01)  
*H05K 3/34* (2006.01)
- (52) **U.S. Cl.**  
 CPC ..... *H01L 23/13* (2013.01); *H01L 23/16* (2013.01); *H01L 23/49816* (2013.01); *H01L 24/81* (2013.01); *H05K 1/111* (2013.01); *H05K 3/0014* (2013.01); *H05K 3/4007* (2013.01); *H05K 3/4697* (2013.01); *H01L 23/49827* (2013.01); *H01L 2224/16225* (2013.01); *H01L 2224/81136* (2013.01); *H01L 2224/81193* (2013.01); *H01L 2224/81801* (2013.01); *H01L 2924/01004* (2013.01); *H01L 2924/014* (2013.01); *H01L 2924/01005* (2013.01); *H01L 2924/01006* (2013.01); *H01L 2924/01029*
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FIG. 1

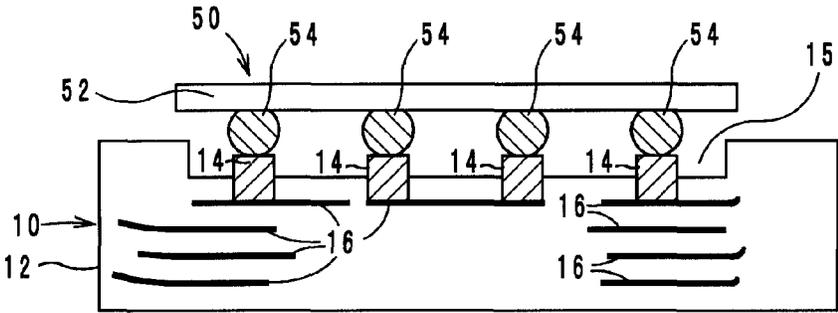
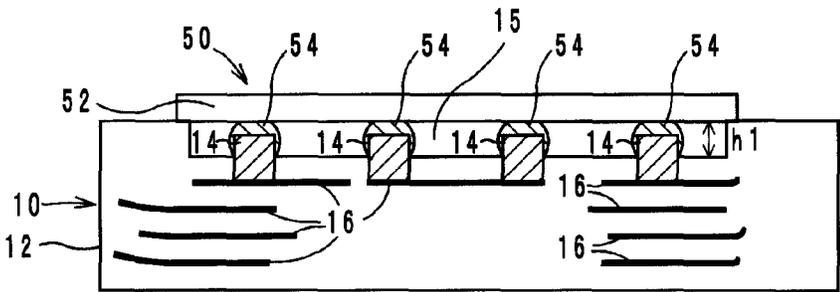
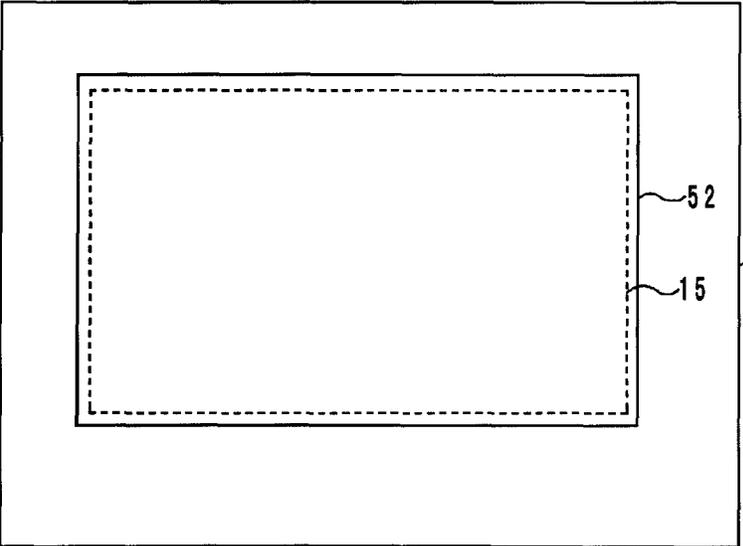


FIG. 2A



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FIG. 2B



60

FIG. 3A

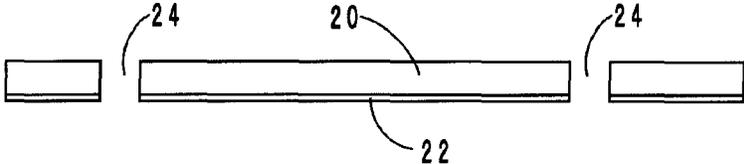


FIG. 3B

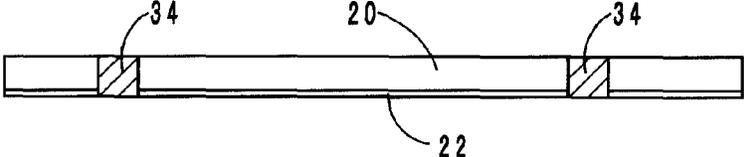


FIG. 3C

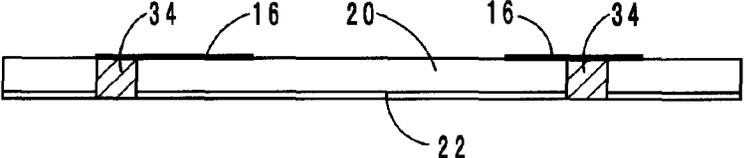


FIG. 4A

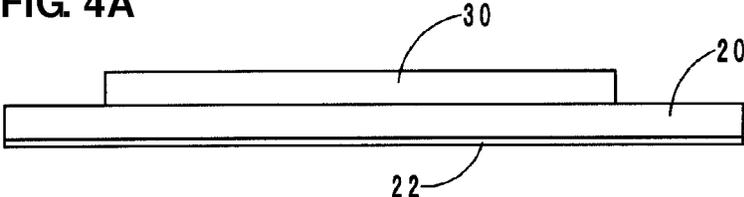


FIG. 4B

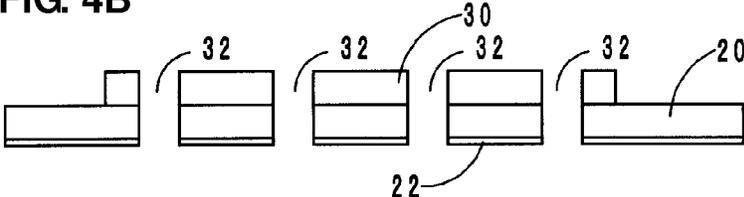


FIG. 4C

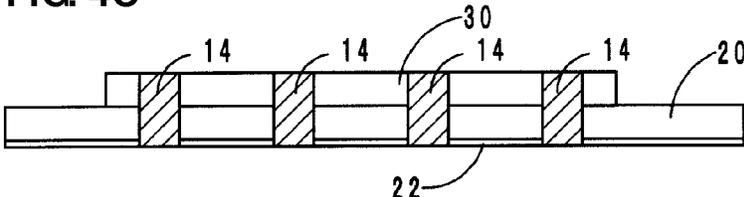


FIG. 5A

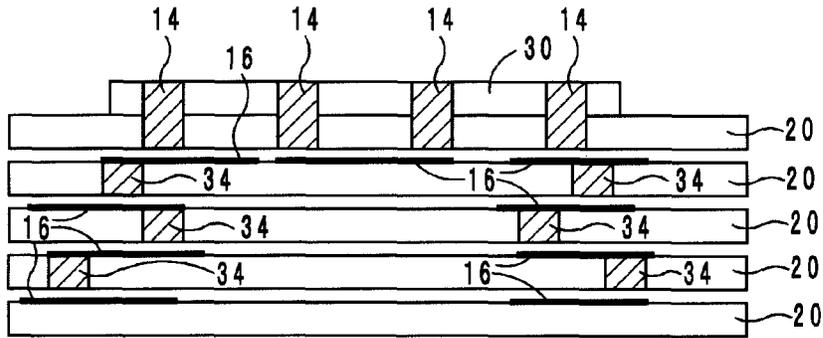


FIG. 5B

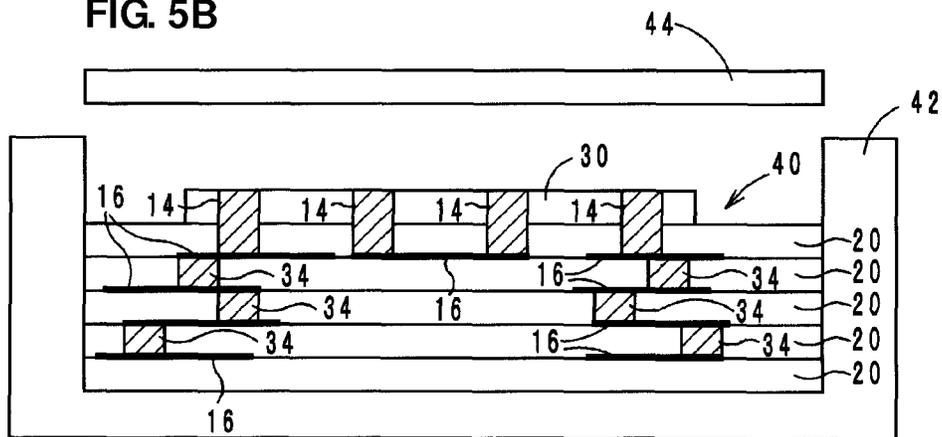


FIG. 6

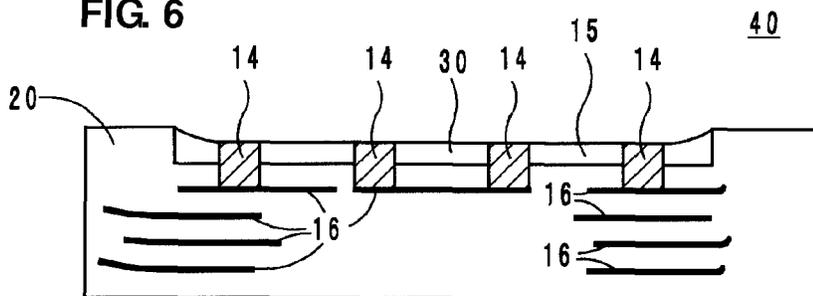


FIG. 7

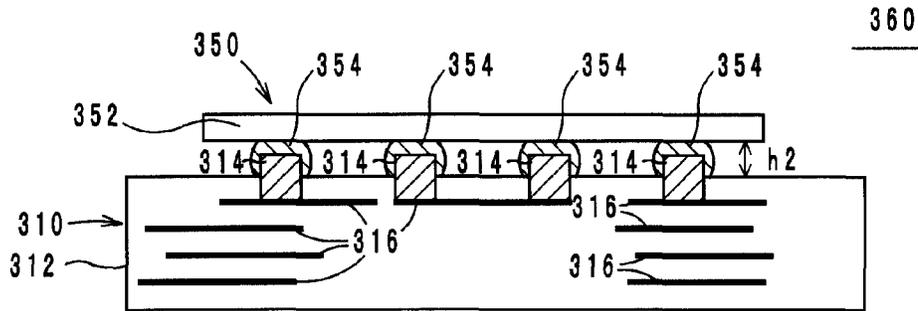


FIG. 8A

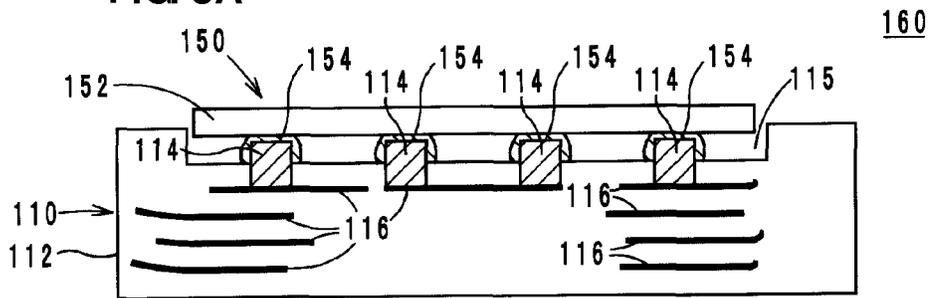


FIG. 8B

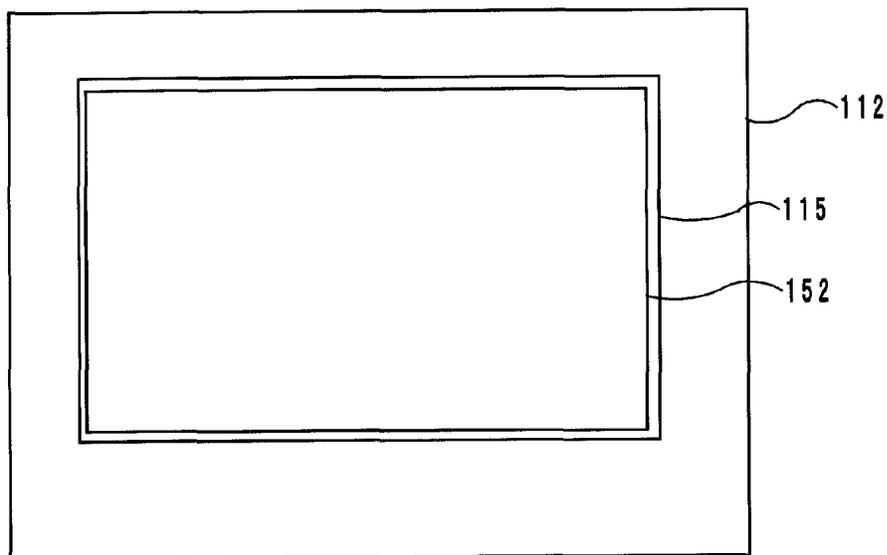


FIG. 9

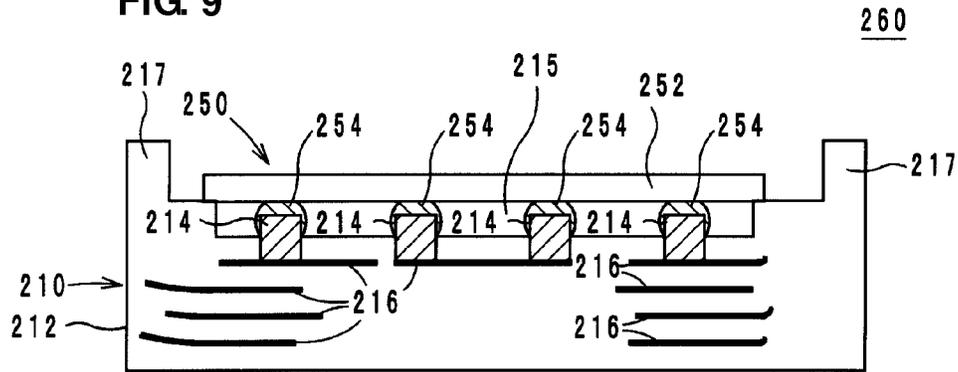


FIG. 10A



FIG. 10B

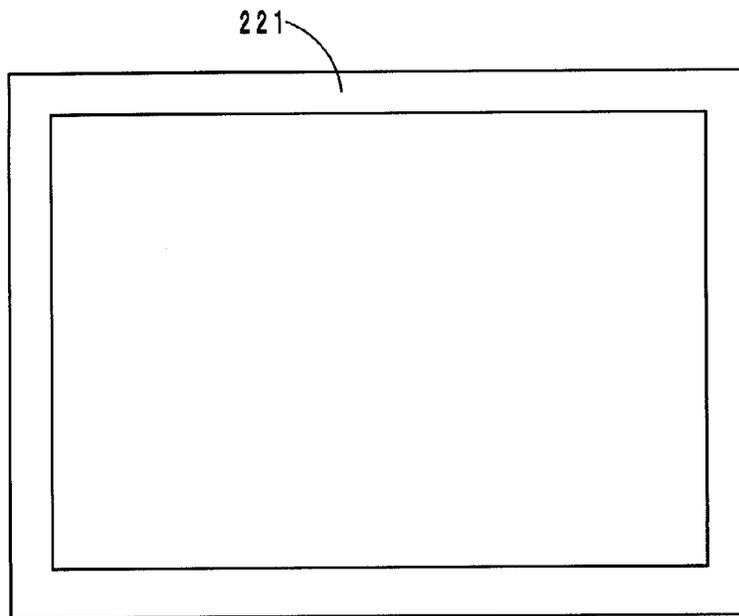


FIG. 11

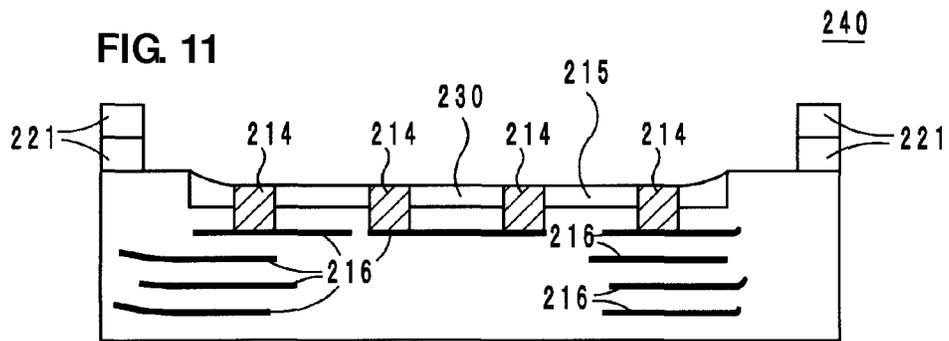


FIG. 12

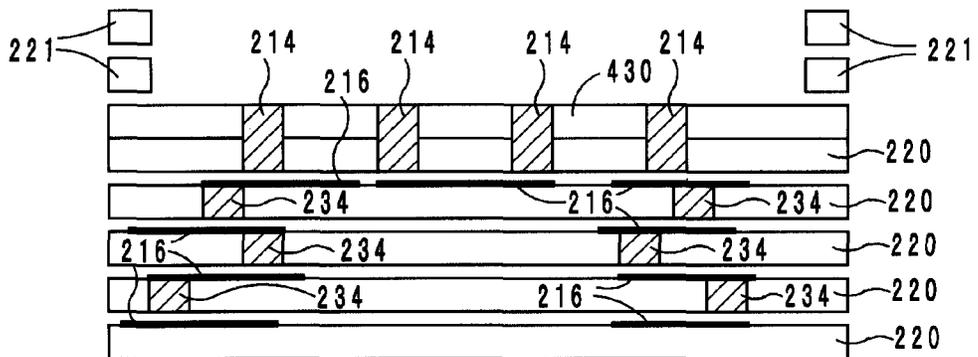


FIG. 13

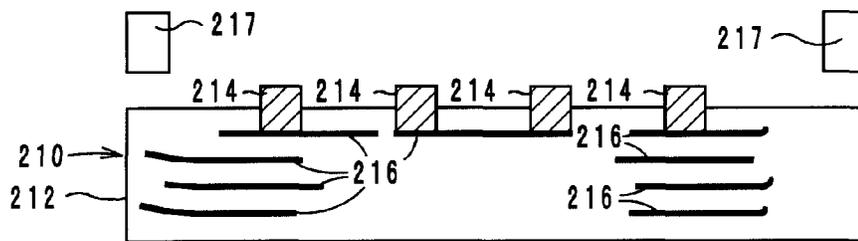


FIG. 14

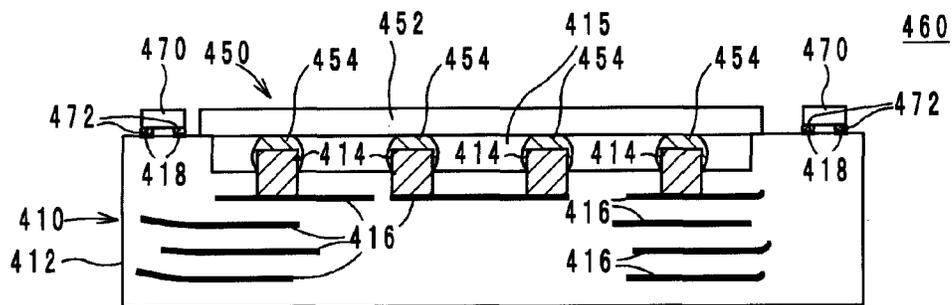


FIG. 15

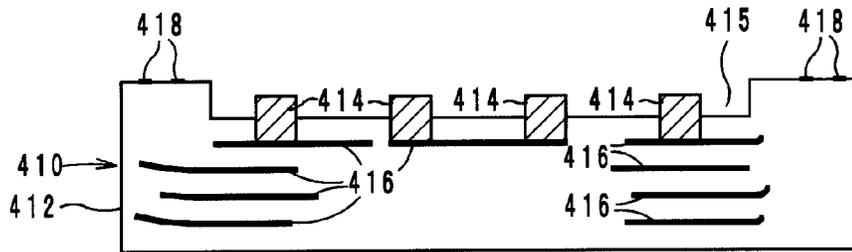


FIG. 16

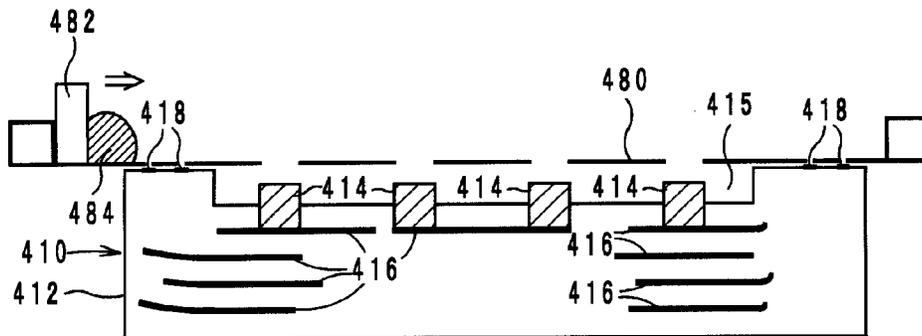


FIG. 17

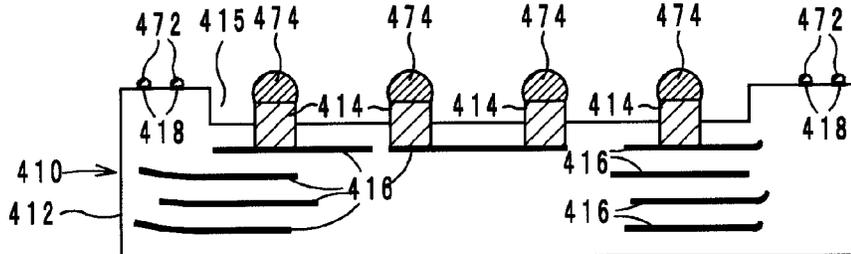


FIG. 18

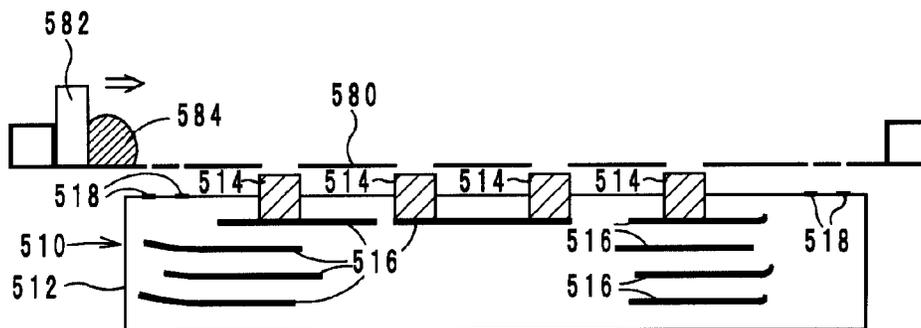


FIG. 19

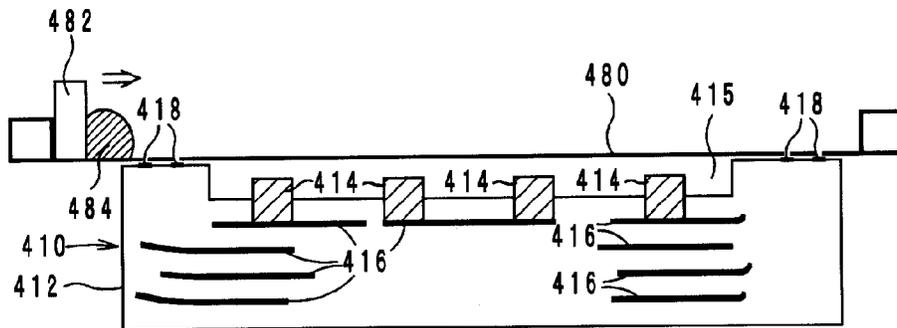


FIG. 20

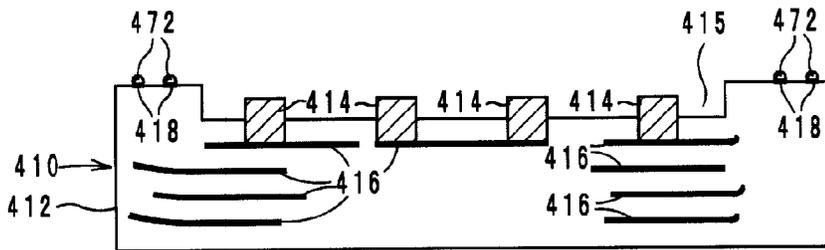


FIG. 21

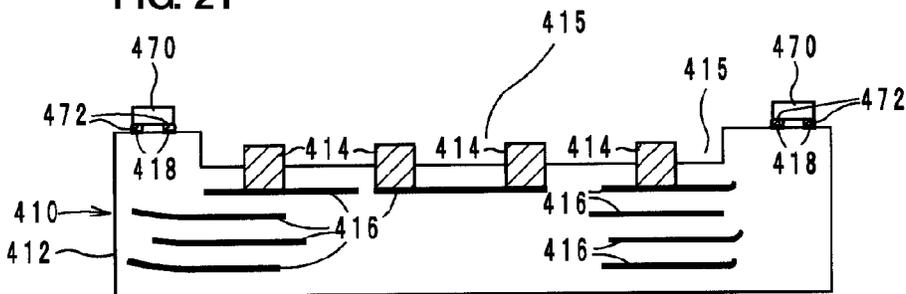


FIG. 22

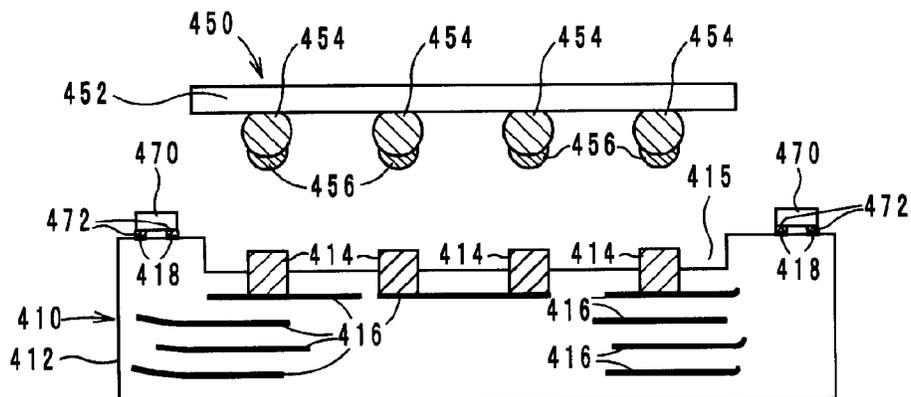
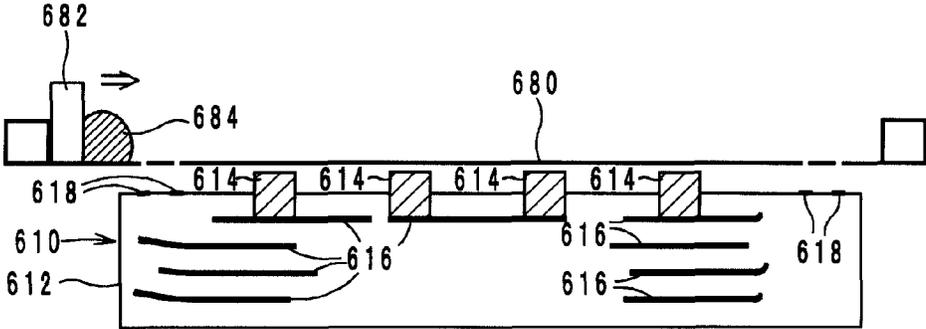


FIG. 23



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## METHOD OF MANUFACTURING A CIRCUIT SUBSTRATE

### BACKGROUND OF THE INVENTION

#### 1. Field of the Invention

The present invention relates to a circuit substrate, a circuit module and a method for manufacturing the circuit substrate, and more specifically, to a circuit substrate on which electronic components are to be mounted, a circuit module and a method for manufacturing the circuit substrate.

#### 2. Description of the Related Art

For mounting an electronic component, such as an IC, on a circuit substrate, the following technique is generally applied. Flat electrode pads are arranged in an array manner on the main surface of a circuit substrate. On the main surface of an IC, solder bumps are formed in an array manner. The IC is placed on the circuit substrate in such a manner that the solder bumps are aligned with the respective electrode pads, and the solder bumps are reflowed. The solder bumps are melted to fix the electrode pads, and the IC is thus mounted on the circuit substrate.

However, the circuit substrate and the IC have different thermal expansion coefficients. Consequently, for example, the circuit substrate may be warped by heat, and, thus, this mounting technique may result in connection failure between the circuit substrate and the IC. Accordingly, Japanese Patent No. 3203731 and Japanese Unexamined Patent Application Publication No. 2005-45143 disclose a semiconductor device substrate on which columnar bumps, but not flat electrode pads, are formed so as to protrude from the main surface thereof.

The columnar bump has a larger height than the electrode pad and is accordingly elastic. Even if the circuit substrate is warped by heat, the columnar bump can absorb the warping. Thus, the semiconductor device substrates disclosed in Japanese Patent No. 3203731 and Japanese Unexamined Patent Application Publication No. 2005-45143 can prevent the occurrence of connection failure between the circuit substrate and the IC.

Such a semiconductor device substrate however increases the height of the circuit substrate by the height of the columnar bumps.

### SUMMARY OF THE INVENTION

Accordingly, preferred embodiments of the present invention provide a thin circuit substrate and circuit module that includes protruding terminals, and a method for manufacturing the circuit substrate.

A circuit substrate is provided on which a first electronic component having a bump is to be mounted. The circuit substrate includes a substrate including a mounting surface on which the first electronic component is to be disposed. The mounting surface includes a recess defined by a recessed portion of the mounting surface. The circuit substrate also includes a terminal to be electrically connected to the bump of the first electronic component. The terminal protrudes from the mounting surface within the recess. The circuit substrate may further include an electrode to which a second electronic component is to be joined. The electrode is disposed on the mounting surface outside the recess.

A circuit module is provided which includes a first electronic component, and a circuit substrate on which the first electronic component is mounted. The first electronic component includes an electronic component body and a bump located on the electronic component body. The circuit sub-

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strate includes a substrate including a mounting surface on which the first electronic component is disposed and including a recess defined by a recessed portion of the mounting surface, and a terminal electrically connected to the bump and protruding from the mounting surface within the recess.

According to a preferred embodiment of the present invention, the recess is formed preferably by recessing a portion of the mounting surface of the substrate. Consequently, the distance from the lower surface of the circuit substrate to the top of the terminal (that is, the height of the circuit substrate) can be smaller than the height of a semiconductor device substrate having a flat mounting surface. Thus, the thickness of a circuit substrate and a circuit module including the circuit substrate can be reduced.

The electronic component body may be disposed within the recess when viewed in the direction of the normal to the substrate.

Alternatively, the electronic component body may cover the recess beyond the edges of the recess when viewed in the direction of the normal to the substrate and be in contact with the substrate.

The circuit module may further include a second electronic component. In this instance, the circuit substrate further includes an electrode on the mounting surface outside the recess. The second electronic component is joined to the electrode with a solder layer therebetween.

According to another preferred embodiment of the present invention, a method of manufacturing a circuit substrate on which a first electronic component having a bump is to be mounted and the circuit substrate includes a terminal to which the bump of the first electronic component is to be electrically connected, includes the steps of forming a mask layer on a portion of a main surface of a first sheet, forming a through-hole in the mask layer, filling the through-hole with a conductive material, stacking a plurality of second sheets and the first sheet having the mask layer such that the mask layer acts as the uppermost layer, and compressing the stack to embed the mask layer in the first sheet, and removing the mask layer from the stack of the first sheet and the second sheets.

The mask layer may be formed by applying a resin paste onto the first sheet in the step of forming the mask layer.

The through-hole may be formed by irradiating the mask layer with a laser beam in the step of forming the through-hole.

In the method, the first sheet and the second sheets may be ceramic green sheets, and the mask layer may be made of a resin. In this instance, the step of removing the mask layer is performed by firing the first sheet and the second sheets together with the mask layer, thereby consuming the mask layer.

The through-hole may be formed so as to pass through the first sheet and the mask layer in the step of forming the through-hole.

The method may further include the steps of forming an electrode in a region other than the mask layer, and printing a solder paste on the electrode through a mask pattern. The electrode is to be joined to a second electronic component.

According to various preferred embodiments of the present invention, the recess is formed preferably by recessing a portion of the mounting surface of the substrate, and a terminal is formed within the recess. Consequently, the height of the circuit substrate can be lower than the height of a semiconductor device substrate having a flat mounting surface. Thus, the thickness of a circuit substrate and a circuit module including the circuit substrate can be reduced.

Other elements, features, steps, characteristics and advantages of the present invention will become more apparent

from the following detailed description of the preferred embodiments with reference to the attached drawings.

#### BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a sectional view of a structure in which an IC is aligned on a circuit substrate according to a first preferred embodiment of the present invention.

FIG. 2A is a sectional view of the structure of a circuit module including an IC and a circuit substrate, and FIG. 2B is a plan view of the circuit module.

FIGS. 3A-3C are sectional views showing a manufacturing process of a circuit substrate.

FIGS. 4A-4C are sectional views showing the manufacturing process of a circuit substrate.

FIGS. 5A and 5B are sectional views showing the manufacturing process of a circuit substrate.

FIG. 6 is a sectional view showing the manufacturing process of a circuit substrate.

FIG. 7 is a sectional view of the structure of a circuit module according to a comparative example.

FIG. 8A is a sectional view of the structure of a circuit module including an IC and a circuit substrate according to a second preferred embodiment of the present invention, and FIG. 8B is a plan view of the circuit module.

FIG. 9 is a sectional view of the structure of a circuit module including an IC and a circuit substrate according to a third preferred embodiment of the present invention.

FIG. 10A is a sectional view of the structure of a ceramic green sheet, and FIG. 10B is a plan view of the ceramic green sheet.

FIG. 11 is a sectional view showing a manufacturing process of a circuit substrate.

FIG. 12 is a sectional view showing a manufacturing process of a circuit substrate according to a comparative example.

FIG. 13 is a sectional view showing a manufacturing process of a circuit substrate according to a comparative example.

FIG. 14 is a sectional view of the structure of a circuit module including an IC and a circuit substrate according to a fourth preferred embodiment of the present invention.

FIG. 15 is a sectional view of a circuit module in a manufacturing process.

FIG. 16 is a sectional view of a circuit module in a manufacturing process.

FIG. 17 is a sectional view of a circuit module in a manufacturing process.

FIG. 18 is a sectional view of the structure of a circuit substrate according to a comparative example.

FIG. 19 is a sectional view of a circuit module in a manufacturing process.

FIG. 20 is a sectional view of a circuit module in a manufacturing process.

FIG. 21 is a sectional view of a circuit module in a manufacturing process.

FIG. 22 is a sectional view of a circuit module in a manufacturing process.

FIG. 23 is a sectional view of the structure of a circuit substrate according to a comparative example.

#### DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

The structures of a circuit substrate and a circuit module according to a first preferred embodiment will now be described with reference to related drawings. FIG. 1 is a

sectional view of the structure in which a semiconductor integrated circuit (hereinafter referred to as IC) 50 is aligned on a circuit substrate 10. FIG. 2A is a sectional view of the structure of a circuit module 60 including the IC 50 and the circuit substrate 10. FIG. 2B is a plan view of the circuit module 60. The plan view mentioned herein refers to a structure viewed in the direction of the normal to the circuit module 60.

The circuit substrate 10 is a base on which an electronic component, or the IC 50, is to be surface-mounted, and includes a substrate 12, terminals 14 and internal conductive layers 16, as shown in FIG. 1. The substrate 12 includes a stack of a plurality of insulating ceramic layers. The substrate 12 includes a recess 15 formed by recessing a portion of the mounting surface thereof on which the IC 50 is to be mounted. In the description hereinafter, the upper surface of the substrate 12 is referred to as the mounting surface, and the surface of the substrate 12 opposing the mounting surface is referred to as the lower surface. In the present preferred embodiment, the mounting surface refers to the visible surface in plan view. More specifically, the mounting surface includes the surface defined by the region outside the recess 15 and the surface defined by the region within the recess 15. The term recessing indicates that a portion of the circuit substrate 10 is deformed by compression.

The internal conductive layers 16 are stacked with the ceramic layers to form the substrate 12. The internal conductive layers 16 are connected to each other through via conductors (not shown) to form a circuit.

The terminals 14 are formed in an array manner in the recess 15 so as to protrude from the mounting surface of the substrate 12, and serve to electrically connect the circuit including the internal conductive layers 16 with the IC 50. Hence, first ends of the terminals 14 are electrically connected to the internal conductive layers 16. The level of the terminal is lower than the level of the mounting surface of the substrate 12 outside the recess 15.

The IC 50 includes an IC body 52 and solder bumps 54. The IC body 52 includes a silicon substrate having a circuit (not shown). The solder bumps 54 are arranged in an array on the lower surface of the IC body 52, and serve to electrically connect the circuit of the IC body 52 with the terminals 14. In the description hereinafter, the upper surface of the IC body 52 is referred to as the upper surface, and the lower surface of the IC body 52 is referred to as the mounting surface.

The circuit substrate 10 and the IC 50 are aligned such that the terminals 14 come in contact with the respective solder bumps 54, as shown in FIG. 1, and are then reflowed. The solder bumps 54 are thus melted to cover the terminals 14, as shown in FIG. 2A. Consequently, the IC 50 is mounted on the circuit substrate 10.

The area of the recess 15 in plan view is smaller than that of the IC body 52. Hence, the IC body 52 is mounted so as to cover the recess 15 beyond the edges of the recess 15 when the circuit module 60 is viewed from above, as shown in FIG. 2B. In this instance, the mounting surface of the IC body 52 is in contact with the mounting surface of the substrate 12, as shown in FIG. 2A.

A method for manufacturing the circuit substrate 10 will now be described with reference to related drawings. FIGS. 3A to 6 are sectional views of the circuit substrate 10 in a manufacturing process.

First, a binder, a plasticizer and a solvent are mixed to a ceramic material powder containing barium oxide, silicon oxide and alumina to prepare a slurry. Subsequently, the slurry is formed into a sheet on a carrier film to prepare a ceramic green sheet by a doctor blade method or any other

sheet forming technique. The ceramic green sheet is cut into pieces having a predetermined size.

After the completion of the ceramic green sheets, layers constituting the substrate **12** are formed. As shown in FIG. 3A, first, through-holes **24** are formed in one of the ceramic green sheets **20** by stamping. Then, the through-holes **24** are filled with a conductive paste mainly containing a conductive material, such as Cu or Ag, to form via conductors **34**, as shown in FIG. 3B.

Subsequently, a conductive paste mainly containing a conductive material, such as Cu or Ag, is printed on the main surface of the ceramic green sheet **20** to form an internal conductive layer **16** having a predetermined pattern. One of the layers constituting the substrate **12** is thus completed through the steps shown in FIGS. 3A to 3C. The series of the steps shown in FIGS. 3A to 3C is repeated until all the layers constituting the substrate are completed.

Then, the uppermost layer of the substrate **12** is formed using one of the ceramic green sheets. More specifically, a resin paste mainly containing polypropylene, butyral or acrylic resin, for example, is screen-printed on a portion of the main surface of the ceramic green sheet **20** to form a mask layer **30**, as shown in FIG. 4A.

After the formation of the mask layer **30**, the ceramic green sheet **20** and the mask layer **30** are subjected to stamping together to form through-holes **32** passing through the ceramic green sheet **20** and the mask layer **30**, as shown in FIG. 4B. Then, the through-holes **32** are filled with a conductive paste mainly containing a conductive material, such as Cu or Ag, to form terminals **14**, as shown in FIG. 4C.

Turning now to FIG. 5A, the mask layer **30** and a plurality of ceramic green sheets **20** are stacked in such a manner that the mask layer **30** overlies the ceramic green sheets **20** so as to act as the uppermost layer. In practice, a carrier film **22** is removed from each ceramic green sheet **20** before stacking the layers. Thus, a multilayer green composite **40** is completed.

Subsequently, the multilayer green composite **40** is placed in a base mold **42**, and the multilayer green composite **40** is compressed by applying a pressure using a mold cover **44** from above to bind the ceramic green sheets **20** and the mask layer **30** together, as shown in FIG. 5B. The compression is preferably performed under conditions of a mold cover **44** temperature of about 70° C. and a mold cover **44** pressure of about 400 kg/cm<sup>2</sup>, for example. Thus, the ceramic green sheets **20** under the mask layer **30** is compressed by the mask layer **30** in the thickness direction, so that the mask layer **30** is embedded in the uppermost ceramic green sheet **20**, as shown in FIG. 6. Thus, the recess **15** is formed. At this time, the internal conductive layers **16** are bent in such a manner that the portions of the internal conductive layers **16** under the mask layer **30** sink downwards, as shown in FIG. 6. In FIG. 6, the boundaries between the ceramic green sheets **20**, and the via conductors **34** are omitted.

Finally, the multilayer green composite **40** including the ceramic green sheets **20** is fired. At this time, the mask layer **30** is consumed (burned down) due to high temperature, and the recess **15** appears. The firing is performed at 990° C. for 1 hour. The circuit substrate **10** as shown in FIG. 1 is thus completed through the above-described process.

The circuit substrate **10** includes a recess **15** formed by recessing a portion of the mounting surface of the substrate **12**, and terminals **14** are formed in the recess **15**. Consequently, the distance from the lower surface of the circuit substrate **10** to the top of the terminal **14** (that is, the height of the circuit substrate) can be smaller than the height of a semiconductor device substrate having a flat mounting sur-

face as disclosed in Japanese Patent No. 3203731. Thus, the thicknesses of the circuit substrate **10** and the circuit module **60** can be reduced. This will be described in detail below.

The semiconductor device substrate disclosed in Japanese Patent No. 3203731 has columnar bumps protruding from the substrate, and a bump-forming sheet corresponding to the mask layer **30** is disposed as the uppermost layer over the entire surface of the substrate. Accordingly, a force is substantially evenly placed on the mounting surface of the substrate for compression, and a recess is not formed in the mounting surface of the substrate.

On the other hand, for forming the circuit substrate **10**, the portions of the ceramic green sheets **20** under the mask layer receive a higher pressure for compression than the other portions of the ceramic green sheets **20**. Consequently, the compression in the stacking direction of the portions of the ceramic green sheets **20** under the mask layer **30** becomes larger by the thickness of the mask layer **30** than that of the other portions of the ceramic green sheets **20** and that of the substrate of Japanese Patent No. 3203731. Thus, the height of the circuit substrate **10** is more reduced by the thickness of the mask layer **30** than that of the semiconductor device substrate. Hence, the thicknesses of the circuit substrate **10** and the circuit module **60** including the circuit substrate **10** can be reduced.

Since the recess **15** is smaller than the IC body **52** when viewed from above, as shown in FIG. 2B, the mounting surface of the IC body **52** comes in contact with the mounting surface of the substrate **12** when the IC **50** is mounted on the circuit substrate **10**. Consequently, the substrate **12** and the IC body **52** can maintain a distance to some extent therebetween so as to prevent the solder bumps **54** from being excessively compressed to cause a short circuit between adjacent solder bumps **54**. The reason will be described below with reference to FIGS. 2A and 7. FIG. 7 is a sectional view of the structure of a circuit module **360** according to a comparative example. Let the distance between the mounting surface of the substrate **12** and the mounting surface of the IC body **52** be  $h1$  in FIG. 2A. Also, in FIG. 7, let the distance between the mounting surface of the substrate **312** and the mounting surface of the IC body **352** be  $h2$ .

In the circuit module **360** shown in FIG. 7, an IC **350** is mounted on a circuit substrate **310** whose mounting surface does not have a recess. In this instance, since the mounting surface of the IC body **352** does not come in contact with the mounting surface of the substrate **312**, the terminals **314** can be inserted in the solder bumps **354** to a larger depth than those of the circuit module **60** shown in FIGS. 2A and 2B. Accordingly, the distance  $h2$  between the mounting surface of the substrate **312** and the mounting surface of the IC body **352** is smaller than the distance  $h1$  between the substrate **12** and the IC body **52**.

If the solder bump **54** and the solder bump **354** have the same volume before mounting, the volume of the terminal **14** embedded in the solder bump **54** in the circuit module **60** shown in FIGS. 2A and 2B is smaller than that in the circuit module **360** shown in FIG. 7. Accordingly, the form of the solder bump **54** of the circuit module **60** shown in FIGS. 2A and 2B becomes smaller than that of the solder bump **354** of the circuit module **360** shown in FIG. 7. Consequently, the distances between the solder bumps in the circuit module **60** become larger than those in the circuit module **360**, thus preventing short-circuiting.

For the circuit module **60**, the through-holes **32** are formed in the ceramic green sheet **20** and the mask layer **30** at one time in the step shown in FIG. 4B. This can prevent the misalignment between the through-holes **32** formed in the

ceramic green sheet **20** and the through-holes **32** formed in the mask layer **30**. This will be further described below.

If the mask layer **30** is formed of, for example, a resin sheet, but not of a resin paste, the through-holes **32** of the mask layer **30** and the through-holes **32** of the ceramic green sheet **20** are formed in different steps. In this instance, the through-holes **32** are formed in the ceramic green sheet **20** and the mask layer **30** separately, and then the mask layer **30** is disposed on the ceramic green sheet **20**. Therefore, the through-holes **32** of the ceramic green sheet **20** and the through-holes **32** of the mask layer **30** can be misaligned unless the mask layer **30** is disposed on the ceramic green sheet **20** with precise alignment. For the circuit module **60**, on the other hand, the through-holes **32** are formed in the ceramic green sheet **20** and the mask layer **30** at one time, thus preventing misalignment of the through-holes **32**.

The structures of a circuit substrate and a circuit module according to a second preferred embodiment will now be described with reference to related drawings. FIG. **8A** is a sectional view of the structure of a circuit module **160** including an IC **150** and a circuit substrate **110**. FIG. **8B** is a plan view of the circuit module **160**. In the following description, differences of the circuit module **160** from the circuit module **60** of the first preferred embodiment will be mainly described.

In the circuit module **160**, the area of the recess **115** in plan view is larger than that of the IC body **152**. Accordingly, the IC body **152** is disposed within the recess **115** when the circuit module **160** is viewed from above, as shown in FIG. **8B**. In this state, the level of the mounting surface of the IC body **152** is lower than the level of the mounting surface of the substrate **112** outside the region of the recess **115**, as shown in FIG. **8A**.

Thus, the distance from the lower surface of the substrate **112** to the upper surface of the IC body **152** (that is, the height of the circuit module **160**) is shorter than the distance from the lower surface of the substrate **12** to the upper surface of the IC body (that is, the height of the circuit module **60**). Hence, the thickness of the circuit module **160** can be more reduced than that of the circuit module **60**. It is preferable that the circuit module **160** be designed to have such a height as can maintain distances between the solder bumps **154** so as to prevent short-circuiting.

The structures of a circuit substrate and a circuit module according to a third preferred embodiment will now be described with reference to related drawings. FIG. **9** is a sectional view of the structure of a circuit module **260** including an IC **250** and a circuit substrate **210**. In the following description, differences of the circuit module **260** from the circuit module **60** of the first preferred embodiment will be mainly described.

The circuit substrate **210** includes a substrate **212** and a frame portion **217** rising from the mounting surface along the sides of the mounting surface. The frame portion **217** loops so as to surround the mounting surface of the substrate **212**. Also, the frame portion **217** is formed such that the level of the upper surface thereof is higher than that of the upper surface of the IC body **252**. This structure allows the IC **250** to be sealed by filling the region surrounded by the frame portion **217** with a resin. In the present preferred embodiment, the mounting surface of the substrate **212** refers to the region surrounded by the frame portion **217**, not including the upper surface of the frame portion **217**.

The upper surface of the frame portion **217** lies at a level higher than the upper surface of the IC body **252**. The structure of the circuit substrate **210** allows the distance from the lower surface of the substrate **212** to the upper surface of the IC body **252** to be reduced, as in the circuit substrate **10**. Consequently, the level of the upper surface of the frame

portion **217** can be lowered by the degree in which the level of the IC body **252** lowers. In the circuit module **260**, the distance from the lower surface of the substrate **212** to the upper surface of the frame portion **217** (that is, the height of the circuit module **260**) can thus be reduced. Hence, the thicknesses of the circuit substrate **210** and the circuit module **260** can be reduced.

The circuit substrate **210** can be manufactured by the following method. A method for manufacturing the circuit substrate **210** will now be described with reference to FIGS. **10A**, **10B** and **11**. FIG. **10A** is a sectional view of a ceramic green sheet **221**. FIG. **10B** is a plan view of the ceramic green sheet **221**. FIG. **11** is a sectional view showing a step of the manufacturing process of the circuit substrate **210**.

The ceramic green sheet **221** defines the frame portion **217**, and has such a shape as is formed by stamping the center of a rectangular sheet, as shown in FIG. **10B**. A carrier film **222** is bonded to the rear surface of the ceramic green sheet **221**. The ceramic green sheet **221** is disposed on the multilayer green composite **40** shown in FIG. **6** after the carrier has been removed therefrom, and then compression bonding is performed. The compression bonding is performed at a pressure of about 200 kg/cm<sup>2</sup>, for example. The resulting composite is referred to as a multilayer green composite **240**. The multilayer green composite **240** includes two ceramic green sheets **221**.

Subsequently, the multilayer green composite **240** is fired in the same manner as in the method of the circuit substrate **10** according to the first preferred embodiment. In this step, the mask layer **230** is burned down and removed due to high temperature and the recess **215** appears. The circuit substrate **210** as shown in FIG. **9** is thus completed through the above-described process.

The above-described method of the present preferred embodiment can provide a circuit substrate **210** including the frame portion **217**. The detail will be described below with reference to FIGS. **12** and **13**. FIGS. **12** and **13** are sectional views showing steps of a manufacturing process of the circuit substrate **210** according to a comparative example. In the process according to the comparative example, a mask layer **430** is formed of a resin sheet, but not a resin paste. This process will be described in detail below.

In the method according to the comparative example, the mask layer is formed so as to cover the entire surface of the uppermost ceramic green sheet **220**, as shown in FIG. **12**. Then, additional ceramic green sheets **221** intended for the frame portion **217** are disposed on the mask layer **430**. The ceramic green sheets **220**, the ceramic green sheets **221** and the mask layer **430** are compressed together, thereby forming a multilayer green composite. The multilayer green composite is fired. In this step, the mask layer **430** is burned down and removed due to high temperature. The ceramic green sheets **221** disposed on the mask layer **430** as shown in FIG. **12** are separated from the substrate **212**, as shown in FIG. **13**, by removing the mask layer **430**. Hence, the circuit substrate manufacturing method using the resin sheet cannot produce the circuit substrate **210**.

In the circuit substrate manufacturing method according to the third preferred embodiment, on the other hand, the mask layer **230** is formed of a resin paste on a portion of the upper surface of the ceramic green sheet **220**. Thus, the mask layer **230** is not present between the ceramic green sheet **220** and the ceramic green sheets **221**. Consequently, the frame portion **217** is not separated from the substrate **212**.

The structures of a circuit substrate and a circuit module according to a fourth preferred embodiment will now be described with reference to related drawings. FIG. **14** is a

sectional view of the structure of a circuit module **460** including an IC **450** and a circuit substrate **410**. In the following description, differences of the circuit module **460** from the circuit module **60** of the second preferred embodiment will be mainly described.

The difference between the circuit module **60** and the circuit module **460** is that the circuit module **460** includes a circuit substrate **410** including an IC **450** and an electronic component **470** while the circuit module **60** includes a circuit substrate **10** including only the IC **50**. More specifically, the substrate **412** includes land electrodes **418** used for mounting an electronic component **470** on the mounting surface outside the recess **415**. The electronic component **470** is disposed on the land electrodes **418** with a solder layer **472** therebetween.

A method for manufacturing the circuit module **460** will now be described with reference to related drawings. FIGS. **15** to **17** are sectional views of the circuit module **460** in steps of the manufacturing process.

First, the steps shown in FIGS. **3A** to **6** are performed in the same manner as in the manufacturing process of the circuit substrate **10** according to the first preferred embodiment, and the same description will be omitted. Subsequently, land electrodes **418** are formed on the mounting surface outside the recess **415**, as shown in FIG. **15**. The land electrodes **418** are formed by, for example, applying an electroconductive paste mainly containing Cu, followed by firing. The firing of the land electrodes **418** may be performed simultaneously with the firing of the multilayer composite.

Turning now to FIG. **16**, a metal mask **480** including openings corresponding to the terminals **414** and the land electrodes **418** is aligned on the circuit substrate **410**. Then, a squeegee **482** is moved on the metal mask **480** in the arrow direction to print a solder paste **484** through the metal mask **480**. Thus, solder layers **472** and **474** are printed on the terminals **414** and the land electrode **418**, as shown in FIG. **17**. Subsequently, an electronic component **470** and an IC **450** are mounted to complete the circuit module **460** shown in FIG. **14**.

The circuit substrate **410** of the present preferred embodiment can prevent the terminals **414** from breaking, and prevent the solder layers **472** from being displaced and undesirably spreading, as described below with reference to related drawings. FIG. **18** is a sectional view of the structure of a circuit substrate **510** according to a comparative example.

The circuit substrate **510** shown in FIG. **18** is different from the circuit substrate **410** shown in FIG. **14** in that the recess **415** is not formed. In order to print solder layers on the terminals **514** and the land electrodes **518** of such a circuit substrate **510**, the metal mask **580** is disposed on the circuit substrate **510**, and a solder paste **584** is printed using a squeegee **582**.

In order to prevent the solder layers from being displaced when the solder paste **584** is printed, the metal mask **580** should be disposed close to the mounting surface of the substrate **510**. However, the circuit substrate **510** shown in FIG. **18** includes terminals **514** protruding upward from the mounting surface of the substrate **512**. If the metal mask **580** is disposed excessively close to the circuit substrate **510** to prevent the solder layers from being displaced or undesirably spreading, the squeegee **582** may come in contact with the terminals **514** to break the terminals **514**. On the other hand, if the metal mask **580** is disposed excessively distant from the mounting surface of the circuit substrate **510** to prevent the terminals **514** from being broken, the printed solder layers are displaced or undesirably spread because of the large distance between the metal mask **580** and the terminals **514** and land electrodes **518**.

On the other hand, in the circuit substrate **410** including the recess **415**, the terminals **414** are formed within the recess **415**. Consequently, the possibility that the squeegee **582** comes into contact with the land electrodes **418** is low even though the metal mask **480** is disposed close to the land electrodes **418**. In addition, the distance between the land electrodes **418** and the metal mask **480** in the circuit substrate **410** can be more reduced than that in the circuit substrate **510**, as shown in FIGS. **16** and **18**. Accordingly, the displacement and undesired spread of the printed solder layer **472** can be prevented particularly on the land electrodes **418**.

The circuit substrate **410** and the circuit module **460** according to the fourth preferred embodiment may be produced by the following manufacturing method. FIGS. **19** to **22** are sectional views of the circuit module **460** in steps of the manufacturing process.

First, the steps shown in FIGS. **3A** to **6** are performed in the same manner as in the manufacturing process of the circuit substrate **10** of the first preferred embodiment, and the same description will be omitted. Subsequently, land electrodes **418** are formed on the mounting surface outside the recess **415**, as shown in FIG. **15**. The land electrodes **418** are formed by, for example, applying an electroconductive paste mainly containing Cu, followed by firing. The firing of the land electrodes **418** may be performed simultaneously with the firing of the multilayer composite.

Turning now to FIG. **19**, a metal mask **480** having openings corresponding to the land electrodes **418** is aligned on the circuit substrate **410**. This metal mask **480** does not have openings corresponding to the terminals **414**. Then, a squeegee **482** is moved on the metal mask **480** in the arrow direction to print a solder paste **484** through the metal mask **480**. Thus, solder layers **472** are printed on the land electrodes **418**, as shown in FIG. **20**.

Subsequently, an electronic component **470** is mounted on the land electrodes **418** with the solder layers **472** therebetween, as shown in FIG. **21**. Then, an IC **450** having solder bumps **454** coated with a flux **456** is disposed on the terminals **414**, as shown in FIG. **22**. The reflowing temperature for mounting the electronic component **470** and the IC **450** is, for example, about 260° C. The circuit module **460** is thus completed through the above-described process.

The circuit substrate **410** of the present preferred embodiment can prevent the top ends of the terminals **414** from being crushed, and prevent the solder layers **472** from being displaced and undesirably spreading, as described below with reference to related drawing. FIG. **23** is a sectional view of the structure of a circuit substrate **610** according to a comparative example.

The circuit substrate **610** shown in FIG. **23** is different from the circuit substrate **410** shown in FIG. **14** in that the recess **415** is not formed. In order to print solder layers on the terminals **614** and the land electrodes **618** of such a circuit substrate **610**, the metal mask **680** is disposed on the circuit substrate **610**, and a solder paste **684** is printed using a squeegee **682**.

In order to prevent the solder layers from being displaced when the solder paste **684** is printed, the metal mask **680** should be disposed close to the mounting surface of the substrate **610**. However, the circuit substrate **610** shown in FIG. **23** has terminals **612** protruding upward from the mounting surface of the substrate **614**. If the metal mask **680** is disposed excessively close to the circuit substrate **610** to prevent the solder layers from being displaced or undesirably spreading, the metal mask **680** may be pressed on the terminals **614** to crush the top ends of the terminals **614**. On the other hand, if the metal mask **680** is disposed excessively distant from the

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mounting surface of the circuit substrate **610** to prevent the terminals **614** from being crushed, the solder layers are displaced or undesirably spread because of the large distance between the metal mask **680** and the terminals **614** and land electrodes **618**.

On the other hand, in the circuit substrate **410** having the recess **415**, the terminals **414** are formed within the recess **415**. Consequently, the possibility that the metal mask **480** comes into contact with the land electrodes **418** is low even though the metal mask **480** is disposed close to the land electrodes **418**. In addition, the distance between the land electrodes **418** and the metal mask **480** in the circuit substrate **410** can be more reduced than that in the circuit substrate **610**, as shown in FIGS. **19** and **23**. Accordingly, the displacement and undesired spread of the printed solder layer **472** can be prevented particularly on the land electrodes **418**.

The solder bumps **454** may be coated with a solder paste instead of the flux **456**.

Although the through-holes **24** and **32** in the circuit substrate **10** are preferably formed by stamping, for example, other techniques may be applied to form the through-holes **24** and **32**. For example, the through-holes **24** and **32** may be formed by laser beam machining. If the through-holes **32** are formed by laser beam machining, it is preferable that laser beam be irradiated from the mask layer **30** side. Since the energy of laser beam is consumed to reduce the diameter of the beam while forming the through-holes **32** in the ceramic green sheet **20**, the diameter of the through-hole **32** is increased upward.

As described above, various preferred embodiments of the present invention are useful for circuit substrates, circuit modules and methods for manufacturing circuit substrates, and are particularly superior in that they reduce the thicknesses of circuit substrates and circuit modules including circuit substrates.

While preferred embodiments of the present invention have been described above, it is to be understood that variations and modifications will be apparent to those skilled in the art without departing the scope and spirit of the present inven-

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tion. The scope of the present invention, therefore, is to be determined solely by the following claims.

What is claimed is:

1. A method for manufacturing a circuit substrate on which a first electronic component having a bump is to be mounted, the circuit substrate including a terminal to which the bump of the first electronic component is to be electrically connected, the method comprising the steps of:

- forming a mask layer on a portion of a main surface of a first sheet;
- forming a through-hole in the mask layer;
- filling the through-hole with a conductive material;
- stacking a plurality of second sheets and the first sheet having the mask layer such that the mask layer defines an uppermost layer, and compressing the stack to embed the mask layer in the first sheet; and
- removing the mask layer from the stack of the first sheet and the second sheets.

2. The method according to claim **1**, wherein the mask layer is formed by applying a resin paste onto the first sheet in the step of forming the mask layer.

3. The method according to claim **1**, wherein the through-hole is formed by irradiating the mask layer with a laser beam in the step of forming the through-hole.

4. The method according to claim **1**, wherein the first sheet and the second sheets are ceramic green sheets, and the mask layer is made of a resin, and wherein the step of removing the mask layer is performed by firing the first sheet and the second sheets together with the mask layer, thereby consuming the mask layer.

5. The method according to claim **1**, wherein the through-hole is formed so as to pass through the first sheet and the mask layer in the step of forming the through-hole.

6. The method according to claim **1**, further comprising the steps of forming an electrode to which a second electronic component is to be joined, in a region other than the mask layer, and printing a solder paste on the electrode through a mask pattern.

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